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8. Fluvial Geomorphology and Riparian Habitat

8.1 Introduction

This chapter describes the fluvial geomorphological setting for the Extended, Secondary, and Primary study areas. Descriptions and maps of these three study areas are provided in Chapter 1 Introduction. Fluvial geomorphology describes the origin and development of a river's shape, form, and function as a result of streamflow, sediment, underlying geology, the regional climate, river hydrology, and human-induced changes. These physical relationships affect the associated riparian habitat and wildlife that live there. The fish, wildlife, and riparian vegetation have adapted to the cycle of erosion, deposition, and changing channel pattern. The health and productivity of the fluvial system depend on the periodic rejuvenation associated with large storm events and channel movements.

The regulatory setting for geomorphology is discussed briefly in this chapter, and is presented in greater detail in Chapter 4 Environmental Compliance and Permit Summary.

This chapter focuses primarily on the Sacramento River between Keswick Dam and the Pacific Ocean (a portion of the Secondary Study Area). Impacts in the remainder of the Secondary Study Area, as well as the Primary and Extended study areas, were evaluated and discussed qualitatively. Potential local and regional impacts from constructing, operating, and maintaining the alternatives were described and compared to applicable significance thresholds. Mitigation measures are provided in this EIR/EIS for identified significant or potentially significant impacts, where appropriate. Because none were identified for this resource, no mitigation is included in this chapter.

8.2 Environmental Setting/Affected Environment

8.2.1 Extended Study Area

The Extended Study Area includes the State and federal service areas. It includes the west side of the San Joaquin Valley, the Los Angeles Basin, and the California coast south of the San Francisco Bay Area. These three service areas have no large river systems or catchments, limited groundwater resources, generally have less precipitation than other parts of the State, and depend on water imports to meet water demands. The creeks and rivers are typically short, with little flow during summer months. Intense winter storms can cause flooding and large amounts of sediment and debris to rush down local drainages.

The Feather River watershed upstream of Lake Oroville is also part of the Extended Study Area. It is entrenched in older metamorphic and igneous rocks for the most part, except for the upper reaches where the river flows across several down-dropped fault basins filled with sedimentary deposits.

8.2.2 Secondary Study Area

The Secondary Study Area includes the Trinity, Klamath, and Sacramento rivers. The Trinity River portion extends from downstream of Lewiston Dam to its confluence with the Klamath River. The Klamath River portion includes the reach downstream of the confluence to the Pacific Ocean. The Sacramento River portion begins downstream of Keswick Dam and extends to the Pacific Ocean. It is divided into four reaches, with each reach differing substantially from the adjacent upstream and downstream reaches. These river systems and their major tributaries that comprise the Secondary Study Area are described in more detail below.

8.2.2.1 Trinity and Klamath Rivers

The Trinity River is linked to the Sacramento River by diversions from Lewiston Lake through the Clear Creek Tunnel to Whiskeytown Lake on Clear Creek. Trinity River and Clear Creek water is then diverted to Keswick Reservoir on the Sacramento River. Water from Whiskeytown Lake is also diverted through the Spring Creek Tunnel to Spring Creek and then the Sacramento River. These diversions affect streamflow in the Trinity River, in Clear Creek, and in the Sacramento River. An average of approximately 1,100 cfs of streamflow is diverted from the Trinity River basin into the Sacramento River.

The Trinity and Klamath rivers are both bedrock streams, incised into older metamorphic rocks that generally constrain the channel into narrow gorges. Riparian vegetation generally occurs in a narrow band on both banks of the river. Valley reaches also occur, such as near Weaverville and Hoopa Valley. In these areas where the narrow gorge widens, sand, gravel, and silt deposit on gravel bars to provide a wider riparian corridor.

The existing dams and diversions have affected the geomorphology primarily through the interaction with the riparian vegetation and the altered streamflow. Prior to the development of the Trinity Dam and diversions into the Sacramento River system, floodwaters would periodically remove the established riparian vegetation on stream banks and gravel bars. Large amounts of sediment would move downstream from the watershed and deposit on riffles and bars, providing new spawning habitat, and a new seed bed for vegetation. These infrequent storm events removed the older vegetation and rejuvenated the forest.

The operation of Trinity Dam has removed most of the flood peaks from the hydrograph. As a result, riparian vegetation has constricted the channel and invaded channel bars and riffles. The riparian vegetation has reduced fish habitat, significantly narrowed the channel, and isolated the gravel bars from the channel. Most of the vegetation is old, dating back to the time when Trinity Dam was being constructed. Some old vegetation is currently being removed mechanically, and high scouring flows are being released periodically. Spawning gravel is also being added periodically to riffles downstream of the dam. These flows and the added gravel should assist in returning the Trinity River to a more natural state.

Trinity Dam and Reservoir, their afterbay, and Lewiston Reservoir also affect the movement of sediment by trapping all of the bedload material and most of the suspended material. The river downstream of the dam is starved of sediment, resulting in the washing away of finer material and riffles too coarse for salmon to spawn on. Farther downstream, the removal of high flushing flows has resulted in the deposition of fine sediment from tributaries. The deposition constricts the channel and encourages riparian growth. The sand also deposits on riffles, suffocating salmon eggs and young salmon. Large woody debris is important fish habitat but is also captured by the two reservoirs, resulting in a lack of this type of habitat downstream of the dams. These effects continue to the confluence of the Trinity and the Klamath, and then to the Pacific Ocean, but decrease downstream because tributary inflow of both sediment and water reduce the influence of the dams.

8.2.2.2 Sacramento River

The Sacramento River is the largest and most important river system in California. It drains 17 percent of California’s land area, yet yields 18.4 million acre-feet, (approximately 35 percent of the water supply) annually. The river and its tributaries are the State’s most important watershed for salmon.

The Sacramento River headwaters originate on the east slope of Mt. Eddy in the vicinity of Mt. Shasta. Mt. Shasta provides much of the snowmelt that feeds the upper part of the Sacramento River during early spring months.

From Mt. Shasta, the river is cradled between the Cascade Range on the east and the Klamath Mountains on the west. The river flows into the 4.5 million acre-feet Shasta Lake, and its afterbay, Keswick Reservoir, a few miles upstream of Redding. The river then enters the Redding Basin of the Sacramento Valley, the northern half of the Great Central Valley. The river flows through the center of the approximately 150-mile-long, and 30- to 60-mile-wide, Sacramento Valley. Joining the Sacramento River are numerous smaller tributaries, including Clear, Cottonwood, Thomes, Stony, and Cache creeks on the west side, and Stillwater, Bear, Battle, Mill, Deer, Big Chico and Butte creeks on the east side. The Feather, American, Cosumnes, and Mokelumne rivers are larger tributaries draining the Sierra Nevadas on the east side of the Sacramento Valley. The Sacramento River joins the San Joaquin River in the Sacramento-San Joaquin Delta, and then empties into Suisun, then San Pablo, and finally San Francisco bays. Land elevations vary from 40 feet below sea level in the Sacramento-San Joaquin Delta region, to approximately 500 feet at the valley edge, to over 14,000 feet at Mt. Shasta. The Sacramento Valley is bordered on the east by the Sierra Nevada and Cascade ranges, and on the west by the California Coast Ranges.

The Sacramento River geomorphology from Shasta and Keswick dams to the Pacific Ocean is influenced by existing facilities causing changes in flow, temperature, sediment transport, and other factors. The four reaches of the Sacramento River are: Keswick Dam to Red Bluff, Red Bluff to Colusa, Colusa to Clarksburg, and Clarksburg to the Pacific (Figure 8-1).

Keswick Dam to Red Bluff

The Sacramento River drains approximately 6,500 square miles upstream of Shasta and Keswick dams. This includes the upper Sacramento, Pit, and McCloud rivers. An additional 2,400 square miles occur between Redding and Red Bluff, for a total drainage area of 8,900 square miles at Red Bluff.

Between Keswick Dam (at River Mile [RM] 302) and Redding (RM 298), the river flows across highly erosion-resistant Copley Formation metamorphic rocks. The river is stable, meaning that the river will remain in the current channel and retain about the same geomorphologic characteristics for the foreseeable future. The river is referred to as a bedrock stream because it flows across, and is incised into, older stable geologic formations. Boulders and cobbles are the most common bed material, because finer material has been eroded from the bed, and replacement material is being trapped by the dams. Salmon spawning gravel is being trucked in and injected into the river downstream of Keswick Dam to mitigate for this, providing some spawning gravel in the reach between Keswick and Redding.

Downstream of Redding, the river cuts through Plio-Pleistocene sedimentary deposits of the Tehama Formation, and volcanic-sedimentary deposits of the Tuscan Formation. These two formations are erosion resistant, with only minor river movement expected. The river is still considered mostly a bedrock stream. Bedrock streams are generally not affected to a large degree by changes in streamflow or sediment.

In places along this reach, the Tehama and Tuscan formations form vertical banks several hundred feet or more high. Volcanic basalts and andesites, flowing down from the Cascade Ranges to the east, show evidence of damming the river for short periods of time in the past. One such flow occurs at Table Mountain near Jellys Ferry, and another at Paynes Creek.

Bright red gravelly deposits of the Pleistocene Red Bluff Formation are exposed on top of the older Tehama-Tuscan formations. The sources of these gravels were glacial streams from the surrounding mountains to the east, west, and north.

Terrace deposits occur in places. These are typically flat benches inset into the older deposits. Four terrace levels are generally present, with the older terraces being higher than the younger terraces.

A few places in this reach are mostly alluvium, resulting in erodible unstable banks. In these places, the river may move its channel several thousand feet before encountering more resistant deposits.

For the most part, the river is stable, with only minor bank erosion occurring in alluvial reaches. The river is entrenched, having cut down through hundreds of feet of older rocks and deposits. Iron Canyon, north of the City of Red Bluff, is a dramatic example. Several large bends occur in the lower section of this reach, with one near Jellys Ferry and another in the Bend area.

Three larger and several smaller tributaries join the Sacramento River in this reach. Clear Creek drains the metamorphic and igneous rocks west of Redding. Whiskeytown Dam controls the flows in Clear Creek, and also receives Trinity River water. The creek downstream of the dam is entrenched in a canyon consisting of erosion-resistant metamorphic rocks. The downstream end of the creek is underlain by Tehama Formation and is flanked by terrace deposits. Extensive terrace deposits on the north side of the creek were dredged for gold, leaving dredger tailings that are subsequently being mined for sand and gravel. Gravel mining was also done in the channel, and coupled with the capture of bedload by the reservoir, have resulted in channel incision and loss of salmon spawning riffles. Several gravel bars and riffles have been re-constructed to mitigate for this loss. Gravel injection has also been done by placing spawning gravel along banks, and allowing the deposit to erode during high flows.

Cottonwood Creek also drains the west side of the valley, but the underlying rocks are mostly sedimentary shale, siltstone, sandstone, and conglomerate of the Great Valley Sequence. Upstream, the North Fork, Middle Fork, and South Fork originate in the Klamath Mountains and Coast Ranges. The lower ten miles of the creek is alluvial, with sediment deposition, bank erosion, and meandering creating a broad riparian corridor.

The construction of Shasta, Keswick, and Whiskeytown dams in the watershed has resulted in the capturing of bedload sediment that would normally supply the downstream reaches. The dams capture all the bedload moving in from the upstream watershed, and release clear water. The tributaries in the upper part of this reach are too small to provide sufficient bedload sediment. Cottonwood Creek is the first creek to provide a substantial amount of sediment.

Battle Creek drains the volcanic rocks of the Cascade Range on the valley’s east side. Battle Creek does not produce much sediment, but cool clear springs in the upper part of the watershed provide a year-round flow. Hydroelectric project dams and diversions occur, blocking upstream migration of salmonids, but some of these are planned for removal. The Battle Creek Fish Hatchery, built to mitigate for Shasta Dam, can attract tens of thousands of returning Chinook salmon and steelhead into Battle Creek each year.

The Sacramento River in this reach has a boulder, cobble, and gravel bed for the most part. The channel upstream of the confluence with Cottonwood Creek has mostly an armored stream bed, a condition where finer particles have been eroded, leaving a much coarser surface deposit. Most of the salmon spawning riffles between Redding and the Cottonwood Creek confluence are too coarse for the salmon to spawn in, despite efforts to mitigate for this with salmon spawning gravel injections.

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Red Bluff to Colusa

The riparian corridor between Red Bluff and Colusa is one of the richest and most diverse wildlife habitats remaining in California. The river reach from Red Bluff to Colusa is substantially different from the Keswick Dam to Red Bluff reach. At Red Bluff (RM 243), the Sacramento River exits from the canyon and flows onto the broad alluvial plains of the Sacramento Valley. At that location, the river flows across its own deposits of sand, silt, and gravel. Both the bed and the banks consist of erodible alluvium resulting in a river whose form and function vary greatly with changes in streamflow, sediment, underlying geology, bank composition, climate, and human activities. The watershed increases in size by 3,190 square miles, for a total watershed area of 12,090 square miles at Colusa (RM 144).

In this reach, bank erosion is a normal, natural, and essential element of the landscape. The fish, wildlife, and riparian vegetation have adapted to the cycle of erosion, deposition, and changing channel pattern in which the river meanders slowly back and forth across a broad meander belt. The health and productivity of the system at any one point depends on the periodic rejuvenation associated with these channel movements.

Streamflow is a major determinant of the amount of erosion that occurs. Therefore, this more erodible reach of the river will be affected by dams and diversions that reduce streamflow.

In meandering river systems, erosion is generally associated with the outside (concave side) of the bends (Figure 8-2). Point bars form on the inside (convex side) of channel bends where lower flow velocities cause sediment to deposit. The combination of erosion of outside bends and deposition on point-bars results in channel migration. Over the long term, the river width and profile does not significantly change because erosion and deposition are generally in balance.

Over time, this process of erosion and deposition creates a broad alluvial floodplain. Channel movement is often incremental and the bends in the river gradually move downstream. The channel will move back and forth, re-working much of the same area. This area is referred to as a meander belt. On each side of the meander belt, there are older deposits that are generally more erosion resistant. These older deposits are generally referred to as geologic control in that they tend to constrain the meander belt.

Erosion rates and meander rates vary widely, depending on a number of different variables. Bank composition is a major factor, with the more clay-rich banks and gravelly banks less erodible, and the sandy banks being more erodible. In some places, the river impinges on geologic control at the edge of the meander belt, reducing the erosion rate.

Stream discharge is another factor. Changes in flow resulting from Shasta, Keswick, Whiskeytown, and Black Butte reservoirs have affected bank erosion rates to some degree. By comparing pre-Shasta to post Shasta meander lines, estimates of bank erosion can be calculated. The pre-Shasta 1896 to 1946 bank erosion rate, as calculated by the U.S. Army Corps of Engineers (USACE), is 1.94 acres per mile per year (16 feet per year) between Red Bluff and Colusa (USGS, 1977). The rate between Chico Landing and Colusa was significantly lower after Shasta Dam was constructed (USGS, 1977). The bank erosion rate was 14 feet per year between Red Bluff and Ord Ferry for the period 1977 to 1987. The calculated post-Shasta rate was 16.2 feet per year from 1976 to 1997 for the Red Bluff to Colusa reach, but this short time includes the 1997 flood event, which skews the data (DWR, 2010). Note that the calculated rates depend to a large degree on the period selected and the inclusion of major storm events.

Bank curvature is also a major factor controlling meandering. Generally, the erosion rate is higher, the more that a river curves. However, with higher curvature, there is an increasing tendency for chute cutoffs to occur. Chute cutoffs create a new channel across the bend, straightening the channel. This can occur in a single high flow event. The old channel may fill with sediment or may form an oxbow lake (formed when bends are cut off) separated from the new channel.

The Red Bluff to Colusa reach may be divided into a number of sub-reaches based on fluvial geomorphology. In general, short straight reaches with lower gradient are separated by longer more winding, or sinuous reaches with higher gradient. The sinuosity of a river channel refers to the tightness of its meander loops. A straight reach has a low sinuosity, while a curved reach has a higher sinuosity. The straight reaches generally have some geologic control providing bank stability. Meander migration in the short straight reaches tend to be at a rate of a few hundred feet per 100 years, while in the longer more sinuous reaches, the rate can be as high as 5,000 feet per 100 years.

Bank protection has been installed along the outside of river bends in many places to protect existing land uses, including agriculture, as well as buildings, pumping plants, bridges, and levees. This bank protection stops bank erosion locally, and reduces the average reach-length erosion rate.

These “hard points” will change the rate and pattern of channel movement both upstream and downstream. For example, if the downstream bank of a bend is protected, and the upper bank is left unprotected, then upper bank migration will cause the bend to collapse and be cut off. In other places, bank protection can actually increase bank erosion and meandering, generally by concentrating flows toward an erodible bank downstream, or by inducing a channel bend cutoff. There are also many locations where bank protection was not maintained and the river eventually either eroded around or through the bank protection.

Levees have also been constructed along the river, mostly in the lower half of the reach downstream of Chico Landing near Hamilton City. Levees affect both the river channel and the floodplain. Levees affect the channel by concentrating the flow, increasing velocities and sediment transport. Leveed river sections tend to become deeper, particularly where the levees are close together, because flow velocities are concentrated in one place. Levees generally prevent overbank flow and the deposition of fine sediment over the floodplain. This can cause problems farther downstream when the sediment deposits in weirs, floodways, and bypasses. Levees in these areas are typically set back to the edge of the meander belt and generally founded on geologic control. In most places, at least part of the Sacramento River floodplain is between the levees.

Flood relief structures were built along with the levees to control the amount of flow in the leveed section of the river. Excess flow spills over into the Butte Basin at three of these weirs: the M&T, 3Bs, and Goose Lake flood relief structures. These structures are located at natural depressions in private levees between Chico Landing and Colusa.

Between Chico Landing and Colusa, broad natural levees and wide overflow basins have developed on both sides of the river. Manmade levees have been built on the crest of the natural levees in many places. The Colusa basin drain is on the west side of the river, and the Butte basin on the east. The basins serve as natural flood overflow areas during the winter and as agricultural drains during the irrigation season. The Colusa, Sutter, and Yolo bypasses are broad marshy areas underlain by clayey soils rich in organic deposits. The bypasses convey floodwaters safely out of the basin and into the Sacramento-San Joaquin Delta. They may be flooded for months at a time, but a large percentage of this land is being farmed during the summer.

Agriculture primarily affects the river by the removal of floodplain vegetation. The vegetation acts as a filter, causing the finer sediment to deposit. Vegetation removal on meander bends increases floodflow velocities and increases the likelihood that a chute cutoff will occur. These cutoffs are new channels that

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straighten the river and may reduce the available habitat. Land leveling along the banks of the river generally removes soil from the upstream end and moves it to the downstream end, a process that lowers the upstream bank, thereby increasing the incidence of flooding.

Meander migration rates are important to the species that depend on the habitat variability, riparian forest continuity, and transient features such as oxbow lakes, islands, and point bars. The meandering process creates a wide corridor with a variety of riparian forest ages and stages. Habitat complexity is high, a result of the different soil types, depths to groundwater, and wetland areas.

There is a wide variety of riparian forest species that develop in the meander belt, resulting partially from the different soil types. The clay-rich soils that developed on old oxbow lake deposits support many species. Because of the richness and water-holding capacity, the trees on these soils grow much taller than the surrounding forests. Willow scrub forests develop on the water-side edge of a point bar. Cottonwoods also germinate here, and the survivors develop deeper root systems as deposition continues and the river migrates farther away. Other species include sycamore, alder, box elder, black walnut, Oregon grape, and poison oak.

Over time, the river migrates away, the soils become deeper, and the depth to the groundwater table increases to a point where it becomes too far down for the riparian species to survive. Gradually, valley oak and live oak replace the cottonwoods. Savannahs and seasonal grasslands exist until the river returns to begin the process anew.

Bank swallows depend on bank erosion to create new vertical bank habitat, clean of parasites, and protected from predators. Riparian tree species depend on deposition on the inside of bends to create new seed beds close to the groundwater table. Birds depend on habitat variability caused by bend migration to provide nesting, feeding, and breeding habitats. Fish depend on shade and insect food from streamside riparian vegetation, on large woody debris and tree roots washed into the river for cover, and on fresh gravel washed from eroding banks for spawning.

Bank erosion and meandering also creates complexity in the river channel. Multiple channels, islands, point bars, and pools are formed as a result of the meandering process. Mature trees on the eroding bank are undercut and fall into the river. This large woody debris provides insect food, cover, shade, and holding areas for feeding fish. The large woody debris also creates hydraulic diversity, creating a more complex channel bottom.

Fall-run Chinook salmon spawn in this reach, particularly later in the spawning season when temperatures drop. The spawning gravel is generally appropriately sized and clean—a result of the active meandering which re-works the gravel deposits. Bank erosion supplies new fresh gravel on a yearly basis to the riffle surface. Green sturgeon also use this area.

There are existing diversions in this reach, the larger of which are the T-C Canal at Red Bluff, the GCID Canal upstream of Hamilton City, the M&T Ranch pumps downstream of Hamilton City, the Provident-Princeton-Codora-Glenn pumps downstream of Ord Ferry, the Reclamation District 1004 pumps in Princeton, and the Maxwell Irrigation District pumps downstream of Princeton. The T-C Canal and the GCID Canal are potential sources of water for the Project.

The RBDD, at the upstream end of this reach, historically diverted both water and sediment into the T-C Canal at RM 243. The RBDD will cease operation in September 2011, and will be replaced by the Red Bluff Pumping Plant’s turbine pumps and a new set of fish screens. The Red Bluff Pumping Plant is the first of the three diversion points proposed for the Project. The gaging station that best defines

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hydraulic conditions in this reach of the river is located above Bend Bridge, about ten miles north of Red Bluff

The existing GCID Canal diversion is located approximately five miles upstream of Hamilton City at RM 206. Bank erosion and meander rates have traditionally been high in this area. However, bank protection at the upstream Snaden Island, geologic control exposed on the west bank directly upstream, and a grade control structure (with riprap on both banks) decrease bank erosion susceptibility. Sediment is also diverted at this location. Suspended sediment deposits in the GCID Canal facilities, and bedload depositing in the meander loop is removed periodically. The stream gage that best defines the hydraulic conditions in this reach is at Hamilton City.

Beginning downstream of Hamilton City is a series of flood relief structures, weirs, and bypasses that move excess flood flows out of the Sacramento River and into the adjacent basins. There are three weirs (flood relief structures with a controlled elevation) adjusting the flow remaining in the river: Moulton, Colusa, and Tisdale (Figures 9-2A and 9-2B in Chapter 9 Flood Control and Management). Moulton and Colusa weirs are located a few miles upstream of Colusa. These weirs divert all but 45,000 cfs of flood flows into the Colusa Bypass. The Colusa Bypass then moves the overflow into the Butte Basin, the Sutter Bypass, the Yolo Bypass, and the Sacramento-San Joaquin Delta. The stream gages that best define the hydraulic conditions in this reach are at Butte City and Colusa.

The flood structures are part of the Sacramento River Flood Control Project, authorized by Congress in 1917 and built by USACE. Downstream, Tisdale Weir moves flood water into the Sutter Bypass and then into the Yolo Bypass. Most of the bypass areas are farmed during the agricultural season. However, during floods, much of the weir and bypass areas become spawning and rearing habitat for splittail, and rearing areas for salmonids and other fish species. Some riparian vegetation, sloughs, and wetlands occur in the bypasses, providing habitat for numerous species.

Colusa to Clarksburg

The Sacramento River at Colusa (RM 144) has a watershed area of 12,090 square miles. At the City of Sacramento, the watershed area has increased substantially to 23,502 square miles, the result of the addition of the drainages of the Feather, Yuba, Bear, and American rivers.

Downstream of Colusa to the Sacramento-San Joaquin Delta (beginning at Clarksburg), the river is completely different from the two reaches upstream. Levees built to contain the flow line both banks. The channel capacity is low, approximately 45,000 cfs, with most of the floodwaters diverted out of the channel at Moulton Weir, Colusa Bypass, and Tisdale Weir into the Sutter Bypass. The gradient is also low, and the banks contain cohesive clay, resulting in little erosion and meandering. Riprap has been installed in many areas to protect the banks and levees. The river has also been straightened for navigation in places by cutting a new channel across a bend.

Riparian habitat is generally sparse, with some vegetation along banks. However, in many places, the bank protection is being maintained by the removal of vegetation. Most of the surrounding land has been converted to farms and urban areas, with only a few isolated remnants of riparian forests and oxbow lakes. Riparian habitat is patchy and does not have the complexity and variety typical of the Red Bluff to Colusa reach.

The river channel is also uniform, a single channel with no islands, point bars, or riffles. The bed consists mostly of sand with some gravel. There is very little sediment transport, evidenced by the presence of only a few sand bars. Flood flows are diverted into the bypasses, where most of the fine sediment is deposited.

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The river is a migration corridor for Chinook salmon, steelhead, and green and white sturgeon to spawn in the upper two reaches and for fry heading for the Pacific Ocean. The temperatures are too high, and the gravel too small for salmon spawning downstream of Hamilton City. Numerous warm water species live in this area or migrate through it, including the introduced striped bass and American shad.

Numerous irrigation diversions exist, from small turbine pumps set on the bank, to large reclamation district or municipal pumping plants placed directly on the river.

The Feather River joins the Sacramento River near Verona. The Feather River drainage also includes the Yuba and Bear rivers, for a total watershed area of nearly 6,000 square miles. Hydraulic gold mining in the late 1800s was responsible for huge amounts of sediment being introduced into the lower Feather River. Since then, the channel has been cutting down through these deposits, seeking its pre-mining elevation. The lower ten miles of the Feather River still has abundant and large sand bars slowly moving down the river. Lake Oroville on the Feather River, Englebright Reservoir on the Yuba River, and New Camp Far West Reservoir on the Bear River, impound and control flows and sediment in their respective watersheds. To a lesser extent, the afterbay of the Thermalito Complex, located downstream of Lake Oroville, also affects Feather River flows.

Downstream of the Feather River, the Sacramento River widens substantially. Enormous amounts of fine sediment poured out of the Feather River drainage during the latter part of the 1800s, the result of hydraulic mining for gold. Wood piles were installed in the Sacramento River on both banks in an attempt to concentrate the flow in the center of the channel and keep it free of sand bars. Remnants of these structures are still visible. Dredging to remove sediment was done on a periodic basis during the 1900s to keep the channel open for navigation.

The American River, with an additional 2,000 square miles of watershed, joins the Sacramento River at Sacramento. Hydraulic mining also occurred in this watershed, but the mining activity was not nearly as extensive as on the Feather River. Folsom Reservoir, and its afterbay Lake Natoma, control the flows in this river. The two reservoirs also stop the movement of bedload into the downstream reach of the river, which has resulted in some of the riffles becoming gravel starved with a surface layer containing substrates too coarse for salmon spawning.

Most of the length of the American River from Lake Natoma to its mouth in Sacramento is leveed on both sides of the river. Rock riprap and more biologically friendly forms of bank protection have been installed to protect the levees. Only minimal bank erosion and few channel changes occur.

In some places, tall compacted clay-silt banks of the Laguna Formation (correlated to the Tehama Formation) provide protection from erosion. Tailings, remaining from floating gold dredges, occur in places. Clayey gravels of the Victor Formation (correlated to the Red Bluff Formation) cap some of the ridges.

Clarksburg to the Pacific Ocean

The total watershed area of the Sacramento River, where it joins the San Joaquin River near Collinsville, is 26,332 square miles.

The Sacramento-San Joaquin Delta is a low lying region of the Great Central Valley formed by the confluence of two great river systems, the Sacramento and San Joaquin rivers. The Delta region consists of several islands surrounded by channels. Most of the islands are surrounded by levees protected with rock riprap. Subsidence, caused by farming, wind erosion, and oxidation and burning of peat, has been a problem on many of the islands, with elevations now as low as 40 feet below sea level.

The upstream end of the Delta region begins near the town of Clarksburg (RM 42). Sloughs include Elk, Sutter, Georgiana, Steamboat, Snodgrass, and many others. The sloughs, and the Sacramento River upstream to Sacramento, are affected by tidal influences and salt water intrusion. These sloughs and the river have a surface elevation higher than the interiors of most of the islands. The current geomorphology depends on the levees constructed to prevent flooding. If a levee breaks, an island would be flooded to depths of several tens of feet.

Most of the Delta channels are sand bedded. Velocities tend to be low, even during major floods. During most of the year, tidal flows predominate. Bank erosion is minimal. Most of the levees are protected by rock riprap. Boat wakes and wind-driven waves are the largest causes of bank erosion.

Streamflow in the Delta channels is maintained artificially high during the summer months by releasing additional water from reservoirs. This is done to flush pollutants, reduce salt water intrusion, increase water quality, and to provide fresh water to irrigation pumps and municipal uses in the western part of the Delta.

8.2.3 Primary Study Area

The only location along the Sacramento River within the Primary Study Area where Project construction, operation, and maintenance activities would occur is at the proposed Delevan Pipeline Intake and Discharge Facilities location, on the west side of the Sacramento River at RM 158.5. This location is within the Red Bluff to Colusa Reach of the Sacramento River, approximately five miles south of the Town of Princeton and immediately downstream of the Maxwell Irrigation District pumps.

The Sacramento River, at RM 158.5, is located on erosion resistant deposits (referred to as geologic control) of the Modesto Formation. The Tehama Formation, an older erosion resistant unit, underlies the Modesto Formation at a depth of a few tens of feet. Although the river is currently near the edge of geologic control, it has historically moved back and forth over a thousand feet or more within its narrow meander belt. The river’s meander belt at this location is narrow compared to the upstream and downstream areas. Levees occur on both banks, with the levees 2,000 to 2,500 feet apart. Upstream and downstream, the levees are farther apart; in some locations, more than one mile apart. Bank protection occurs along the east bank in the bend directly upstream.

Bank erosion and deposition are active processes in this area. Figure 8-3 shows the Sacramento River channel meander locations since 1896. A meander is a bend that is moving because of bank erosion. As the bend moves sideways and downstream, the location of deposition also moves downstream. It is expected that the channel will move away from its current location over a period of time.

A point bar that is located on the west bank upstream of the proposed intake facility location has been quite active, moving generally south toward the diversion point. As of 2012, the point bar is located approximately 1,400 feet north of the proposed intake facility location. A second point bar is located directly across the river on the east bank.

The upstream point bar moved downstream approximately 400 feet between 1958 and 1976, or the equivalent of 22 feet per year. In 1981, USACE installed bank protection along the bank across from the point bar, and then extended the bank protection both upstream and downstream in 1987. Between 1976 and 1990, the point bar moved an additional 150 feet, but has not moved in the last 22 years since then. This is a typical point bar reaction to the placement of bank protection, and it is expected that the point bar will not move in the future if the bank protection continues to function.

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The downstream point bar, across from the diversion point on the east bank, also moved downstream for a distance of approximately 1,000 feet between 1958 and 1990, or the equivalent of 31 feet per year. During this time, the river was meandering westward at the same rate as the point bar. Around 1990, the river encountered geologic control (older and more erosion resistant geologic deposits) along the west bank, essentially stopping the migration. Since then, the point bar has not moved.

Sediment movement in the Sacramento River may be high in this location. Suspended sediment levels, consisting mostly of silt and sand, are high during large discharges. High suspended sediment levels are mostly a result of bank erosion occurring upstream, although tributary inflow is also a factor.

River banks in this area generally consist of an upper layer of silt and sand that averages approximately 10 feet thick, and a lower layer of sand and gravel that averages approximately 16 feet thick. When eroded, the upper layer becomes mostly suspended sediment, and the lower layer becomes mostly bedload (sand and gravel). The bedload moves by bouncing along the bottom until it reaches an area with lower velocities, which is generally the next point bar or island downstream. Figure 8-4 shows an abundance of gravel bars and mid-channel islands, suggesting that bedload sediment is abundant in this area.

Moulton Weir is located across and on the opposite side of the river from RM 158.5. This overflow weir, which is part of the Sacramento River Flood Control Project, spills excess water into the Butte Basin during floods. Moulton Weir may affect the movement of bedload sediment. The weir removes water and suspended sediment from the river during high flow events. However, bedload sediment moves along the bottom and does not transport into the weir. The reduced flows in the Sacramento River downstream of the weir have less stream power to move the sediment transported in from upstream, resulting in deposition in this general area.

8.3 Environmental Impacts/Environmental Consequences

8.3.1 Regulatory Setting

The Sacramento River's natural resources that comprise the geomorphology are regulated at the federal and State levels. Provided below is a list of the applicable regulations. These regulations are discussed in detail in Chapter 4 Environmental Compliance and Permit Summary of this EIR/EIS.

8.3.1.1 Federal Plans, Policies, and Regulations

- Coordinated Operations Agreement
- 2009 National Marine Fisheries Service Biological Opinion
- Federal Endangered Species Act
- U.S. Fish and Wildlife Service Operations Criteria and Plan Biological Opinion

8.3.1.2 State Plans, Policies, and Regulations

- Senate Bill 1086
- California Endangered Species Act (CESA) of 1982

8.3.2 Evaluation Criteria and Significance Thresholds

Significance criteria represent the thresholds that were used to identify whether an impact would be significant. Appendix G of the *CEQA Guidelines* does not include criteria that are specific to fluvial geomorphology. The evaluation criteria used for this impact analysis were based on professional

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judgment that considers current regulations, standards, and/or consultation with agencies, knowledge of the area, and the context and intensity of the environmental effects, as required pursuant to NEPA. For the purposes of this analysis, an alternative would result in a significant impact if it would result in any of the following:

- Substantial alteration of natural river processes and characteristics such as bank erosion, sinuosity, gradient, flow velocity, sediment transport, bed coarseness, depth, and width.
- Substantial alteration of natural river meandering, bank erosion, and deposition, with consequent substantial alteration of riparian vegetation regeneration and habitat complexity.
- Substantial alteration of the amount of large woody debris, boulders, shaded riverine aquatic habitat, or spawning gravel in rivers, resulting in substantial loss of fish rearing, holding, spawning, and feeding habitat.

Significance of the impacts on the above-listed geomorphologic parameters was determined by comparing the results from computer models that modeled different scenarios of the proposed operation of the alternatives, checking the parameters for changes that are larger than normal and natural variations over a long study period. The modeled changes that were predictable, consistent, and larger than the observable natural variations in the above-listed parameters would be considered to be significant impacts.

8.3.3 Impact Assessment Assumptions and Methodology

8.3.3.1 Assumptions

The following assumptions were made regarding Project-related construction, operation, and maintenance impacts to river geomorphology:

- Direct Project-related construction, operation, and maintenance activities would occur in the Primary Study Area.
- Direct Project-related operational effects would occur in the Secondary Study Area.
- The only direct Project-related construction activity that would occur in the Secondary Study Area is the installation of an additional pump into an existing bay at the Red Bluff Pumping Plant.
- The only direct Project-related maintenance activity that would occur in the Secondary Study Area is the sediment removal and disposal at the two intake locations (i.e., GCID Canal Intake and Red Bluff Pumping Plant).
- No direct Project-related construction or maintenance activities would occur in the Extended Study Area.
- Direct Project-related operational effects that would occur in the Extended Study Area are related to San Luis Reservoir operation; increased reliability of water supply to agricultural, municipal, and industrial water users; and the provision of an alternate Level 4 wildlife refuge water supply. Indirect effects to the operation of certain facilities that are located in the Extended Study Area, and indirect effects to the consequent water deliveries made by those facilities, would occur as a result of implementing the alternatives.
- The existing bank protection located upstream of the proposed Delevan Pipeline Intake/Discharge facilities would continue to be maintained and remain functional.

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- No additional channel stabilization, grade control measures, or dredging in the Sacramento River at or upstream of the Delevan Pipeline Intake/Discharge facilities would be required.

8.3.3.2 Methodology

For this analysis, the Sedimentation and River Hydraulics Group of the U.S. Bureau of Reclamation conducted computer river hydraulic, sediment, and meander modeling that compared the effects of the four alternatives on natural river processes and characteristics. The USRDOM hydraulic model simulated 82 years of Sacramento River flow (from 1921 to 2003) for each of the alternatives.

Sediment transport models, in conjunction with the USRDOM model, were used to predict sediment transport and changes in bed coarseness, depth, and width. Two sediment transport models were used: one to predict variations in bedload movement, and one for suspended sediment movement.

The USRDOM model simulates daily river flows in the Sacramento River based on the operations specified by the CALSIM II model for each alternative. The monthly CALSIM II results are used to simulate daily reservoir operations and river flows over the period of simulation extending from water year 1922 through 2003 (82-year simulation period). The USRDOM model description and results are included in Appendix 6C. Detailed discussion of the CALSIM II model is provided in Appendix 6B.

The bedload analysis (Appendix 8A) investigated the sediment transport capacity of the Sacramento River from Keswick to Colusa Weir. The river was divided into 15 reaches based on geomorphology and hydrology. The USRDOM model daily flows were used to develop flow duration curves. Bedload transport was calculated using several available equations, with one selected that best described the available observational data. The transport of material greater in size than 2 millimeters was calculated in tons per year for each reach. Using this approach, the aggrading and degrading reaches could be identified, as well as changes in streambed composition predicted over the 82-year simulation period.

The suspended sediment transport model (Appendix 8A) investigated the movement of sediment in the Sacramento River and estimated the amount of sediment that would be diverted at the proposed Project diversions for each alternative. The USRDOM model simulated daily flows were used in conjunction with actual U.S. Geological Survey gaging station sediment sampling results to develop a flow versus suspended sediment rating curve. The rating curve was then used to calculate the sediment transport in the Sacramento River and the amount of sediment entrained in the diversion for each alternative.

The effects on natural river meandering, bank erosion, and deposition in the Sacramento River channel between Red Bluff and Colusa, with consequent effects on riparian vegetation, was modeled using the SRH-Meander model (Appendix 8A). Inputs to the model included USRDOM model daily flows, streambank erodibility, and channel hydraulic characteristics.

The SRH-Meander model simulated the bed topography, flow field, and bank erosion rate in a curved channel with an erodible bank and bed. At the end of each time step, it computed the amount of bank erosion and updated the channel centerline alignment. The amount of bank erosion was calculated using the near-bank depth-averaged flow velocity and a method that incorporated a multiple-size sediment transport equation (Appendix 8A). The model was run with all of the existing riprap in place. The model was calibrated by running the model between 1976 and 1999 using existing conditions and comparing the actual channel changes with the results of modeling. The model was tuned by adjusting the bank erodibility factors until a best-fit between actual and calculated meandering occurred.

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The calibrated SRH-Meander model was run using the USRDOM daily flows from 1980 to 2010 to predict channel meandering from 2010 to 2030. The outputs of the model were a series of maps showing the channel centerline alignment in 2030 for each of the alternatives and graphs showing the accumulated migration distance.

Further, in assessing the impacts to the riparian vegetation along the Sacramento River in the Secondary Study Area, modeling specific to riparian vegetation, including results from the SRH-1DV and SacEFT models, were used. The SacEFT results were also used to analyze impacts to the large woody debris recruitment on the Sacramento River.

The SRH-1DV model simulates the establishment, growth, and mortality of vegetation, in addition to computing hydraulics and groundwater surface in the riparian zone near the river. The simulation tracks daily vegetation changes through 82 years of simulated flow, within the 107 river miles of Sacramento River from upstream of Red Bluff to Colusa. The SRH-1DV analysis focuses on four key valley foothill riparian vegetation types that are representative of the range of riparian communities of the Sacramento River: cottonwood, mixed forest, Gooding’s black willow, and narrow leaf willow. The detailed description of the SRH-1DV model and the associated alternatives evaluation is provided in Appendix 8A.

The SacEFT decision support tool provides key performance measures for various focal aquatic and terrestrial species, and riparian habitat in the Sacramento River. It specifically includes performance measures for evaluating the effects of various flow scenarios on the initiation success and post-initiation scour risk of the Fremont Cottonwood seedlings, and the amount of large woody debris recruited to the mainstem Sacramento River. These performance measures are used as a general indicator for assessing the impacts on riparian vegetation and potential habitat quality in the mainstem Sacramento River in Secondary Study Area. The detailed description of the SacEFT model and the associated alternatives evaluation is provided in Appendix 8B.

8.3.4 Topics Eliminated from Further Analytical Consideration

Because reservoir level fluctuations at San Luis Reservoir would have no effect on geomorphologic processes, only the operational impacts associated with water supply reliability are discussed in the impacts analysis for the Extended Study Area.

Because the existing Red Bluff Pumping Plant and GCID intakes would be the only locations along the Sacramento River where Project construction and/or operation and maintenance activities would occur (and where potential impacts to/from geomorphologic processes as a result of those activities may occur), the remainder of the Secondary Study Area is not discussed.

Because the only location along the Sacramento River where Project construction, operation, and maintenance activities would occur (and where potential impacts to/from geomorphologic processes as a result of those activities may occur) would be at the proposed Delevan Pipeline Intake/Discharge facilities location, potential impacts related to geomorphology are not discussed for the remaining Primary Study Area Project facilities. Similarly, because the proposed Delevan Pipeline Intake/Discharge facilities would not be constructed with implementation of the No Project/No Action Alternative, the Primary Study Area is not discussed for that Alternative.

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8.3.5 Impacts Associated with the No Project/No Action Alternative

8.3.5.1 Extended Study Area – No Project/No Action Alternative

Construction, Operation, and Maintenance Impacts

Agricultural, Municipal, Industrial, and Wildlife Refuge Water Use

Impact Geom-1: Substantial Alteration of Natural River Processes and Characteristics

The No Project/No Action Alternative includes implementation of projects and programs being constructed, or those that have gained approval, as of June 2009. The impacts of these projects have already been evaluated on a project-by-project basis, pursuant to CEQA and/or NEPA, and their potential for impacts to geomorphological processes has been addressed in those environmental documents. Therefore, **there would not be a substantial adverse effect** on natural river processes and characteristics, when compared to Existing Conditions.

Most geomorphologic changes occur as a result of flood flows. Modeling of water supply reliability for the Extended Study Area indicates that changes in flow resulting from changes in water deliveries would be generally small and would occur during summer months when flows are too low to cause significant hydraulic changes. Therefore, **there would not be a substantial adverse effect** on geomorphological processes, when compared to Existing Conditions.

Modeling of water supply reliability for the Extended Study Area indicates that changes in flow resulting from changes in water deliveries would be generally small and would occur during summer months when flows are too low to cause significant hydraulic changes. Population growth is expected to occur in California throughout the period of Project analysis (i.e., 100 years), and is included in the assumptions for the No Project/No Action Alternative. Changes in water deliveries could occur in response to population growth. However, most geomorphologic changes occur as a result of flood flows, and changes in water deliveries would not be expected to result in flood flows. Therefore, **there would not be a substantial adverse effect** on geomorphological processes, when compared to Existing Conditions.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

Refer to the **Impact Geom-1** discussion. That discussion is also applicable to alterations to the river, erosion and deposition, and riparian vegetation and habitat complexity.

Impact Geom-3: Substantial Alteration of the Amount of Large Woody Debris, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

Refer to the **Impact Geom-1** discussion. That discussion is also applicable to effects on fish habitat from alterations to the amount of large woody debris, boulders, shaded riverine aquatic habitat, or spawning gravel.

8.3.5.2 Secondary Study Area – No Project/No Action Alternative

Construction, Operation, and Maintenance Impacts

Trinity Lake, Lewiston Lake, Trinity River, Klamath River Downstream of the Trinity River, Whiskeytown Lake, Spring Creek, Shasta Lake, Sacramento River, Keswick Reservoir, Clear Creek, Lake Oroville, Thermalito Complex (Thermalito Diversion Pool, Thermalito Forebay, and

Thermalito Afterbay), Feather River, Sutter Bypass, Yolo Bypass, Folsom Lake, Lake Natoma, American River, Sacramento-San Joaquin Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay

Impact Geom-1: Substantial Alteration of Natural River Processes and Characteristics

Impacts to the geomorphology of the Klamath, Trinity, and Sacramento River tributaries; the San Joaquin river system; and other elements of the Secondary Study Area depend on the degree of hydraulic alteration associated with the No Project/No Action Alternative. These hydraulic changes and consequent geomorphologic changes as a result of the projects included in the No Project/No Action Alternative would be evaluated pursuant to CEQA and/or NEPA during individual project environmental review, and mitigation would be required for significant geomorphologic impacts during those reviews.

Most of the geomorphologic impacts of this alternative would occur in the Sacramento River between Keswick Dam and the Pacific Ocean, as explained below. Reclamation's computer modeling for the Sacramento River showed minor changes in river flow and flow duration (Appendix 8A).

Modeling results indicate that the Sacramento River annual flow volumes would be comparable between Existing Conditions and the No Project/No Action Alternative (Appendix 8A). There would be a slight decrease in annual flow upstream of the Red Bluff Pumping Plant and a slight increase in flow downstream of the Red Bluff Pumping Plant with the No Project/ No Action Alternative. However, high flows are more geomorphologically significant than lower flows. The changes in high flow events would also be minor and have a low exceedance probability (Appendix 8A).

Modeling results indicate that suspended sediment would continue to be entrained at the Red Bluff Pumping Plant and GCID Canal Intake if the No Project/No Action Alternative were implemented. The existing suspended sediment entrainment rate at the Red Bluff Pumping Plant is estimated to be approximately 4,000 tons[1] per year. Modeling results indicate that this rate would not change if the No Project/No Action Alternative is implemented (Appendix 8A).

Therefore, the amount of suspended sediment that would be entrained at the Red Bluff Pumping Plant with implementation of the No Project/No Action Alternative **would not have substantial adverse effect**, when compared to Existing Conditions**.**

The estimated average amount of suspended sediment currently moving in the river past the Hamilton City stream gage is approximately 3.92 million tons (USACE, 1983).The existing GCID Canal Intake sediment entrainment rate is estimated to be 44,000 tons, representing 1.1 percent of the amount of suspended sediment in the Sacramento River at that location. Modeling results indicate that the amount of suspended sediment that would be entrained at the existing GCID Canal Intake as a result of implementing the No Project/No Action Alternative would be 47,000 tons, representing 1.2 percent of the amount of suspended sediment in the Sacramento River at that location. The slight increase in the amount of sediment diverted, when comparing Existing Conditions to the No Project/No Action Alternative, is less than one-tenth of one percent and is well within natural annual variation. Therefore, implementation of the No Project/No Action Alternative **would not result in a substantial adverse effect** on Sacramento River geomorphology, when compared to Existing Conditions.

[1] In general, 1.5 tons of sediment is equal to one cubic yard.

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Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

Modeling results indicate that impacts to meandering between Existing Conditions and the No Project/No Action Alternative would be minor (Appendix 8A), which **would not result in a substantial adverse effect**.

Impact Geom-3: Substantial Alteration of the Amount of Large Woody Debris, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

The effects on the amount of instream woody material, boulders, shaded riverine aquatic habitat, and spawning gravel are primarily functions of bank erosion. Bank erosion undercuts the banks, and trees fall in the water. The banks are composed of silt, sand, and gravel. The gravel deposits on riffles to form spawning habitat. Because there would be no significant difference in bank erosion between Existing Conditions and the No Project/No Action Alternative, **there would be no substantial adverse effect**.

8.3.6 Impacts Associated with Alternative A

8.3.6.1 Extended Study Area – Alternative A

Construction, Operation, and Maintenance Impacts

Agricultural Water Use, Municipal and Industrial Water Use, and Wildlife Refuge Water Use

Impact Geom-1: Substantial Alteration of Natural River Processes and Characteristics

When compared to Existing Conditions and/or the No Project/No Action Alternative, the amount of alteration to natural river processes and characteristics within the Extended Study Area associated with implementation of Alternative A would be minor. Most geomorphologic changes occur during flood flows. Reservoir releases may increase or decrease as a result of Alternative A operations for water deliveries, but the hydraulic changes would not increase or significantly change flood flows. Therefore, geomorphologic impacts are expected to be **less than significant**, when compared to Existing Conditions and the No Project/No Action Alternative**.**

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

Refer to the **Impact Geom-1** discussion. That discussion is also applicable to alterations to the river, erosion and deposition, and riparian vegetation and habitat complexity.

Impact Geom-3: Substantial Alteration of the Amount of Large Woody Debris, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

Refer to the **Impact Geom-1** discussion. That discussion is also applicable to effects on fish habitat from alterations to the amount of large woody debris, boulders, shaded riverine aquatic habitat, or spawning gravel.

8.3.6.2 Secondary Study Area – Alternative A

Construction, Operation, and Maintenance Impacts

Trinity Lake, Lewiston Lake, Trinity River, Klamath River Downstream of the Trinity River, Whiskeytown Lake, Spring Creek, Shasta Lake, Sacramento River, Keswick Reservoir, Clear Creek, Lake Oroville, Thermalito Complex (Thermalito Diversion Pool, Thermalito Forebay, and Thermalito Afterbay), Feather River, Sutter Bypass, Yolo Bypass, Folsom Lake, Lake Natoma, American River, Sacramento-San Joaquin Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay

Impact Geom-1: Substantial Alteration of Natural River Processes and Characteristics

The Sacramento River from Keswick Dam to the Pacific Ocean is considered to be the main area where Project-related fluvial geomorphology impacts could occur[2]. Compared to Existing Conditions and/or the No Project/No Action Alternative, implementation of Alternative A would result in the Sacramento River experiencing the largest changes in flow and sediment due to hydraulic changes.

The remainder of the Secondary Study Area, including Trinity Lake, Lewiston Lake, Trinity River, the Klamath River, Whiskeytown Lake, Spring Creek, Lake Oroville, Thermalito Complex, Feather River, Sutter Bypass, Folsom Lake, Lake Natomas, or the American River would experience only minor changes in peak flow, and would, therefore, not be expected to substantially alter natural river processes. More noticeable flow changes would occur during the summer, but low summer flows do not substantially alter natural river processes. Also, no Project construction or maintenance activities would occur at any of the above-listed locations. Operational changes resulting in alteration of streamflow would be **less than significant**, when compared to Existing Conditions and the No Project/No Action Alternative, because it would not significantly affect fluvial geomorphology in these areas.

Construction activities associated with the addition of a pump at the Red Bluff Pumping Plant would not occur within the Sacramento River and would not require changes in pumping plant operations. Sediment removal at the Red Bluff Pumping Plant and GCID Canal Intake would occur during the regularly scheduled maintenance period for these intakes and would require the same maintenance activities conducted for Existing Conditions. Therefore, construction activities at the Red Bluff Pumping Plant, and maintenance activities at the Red Bluff Pumping Plant and GCID Canal Intake, are expected to be **less than significant** to Sacramento River geomorphology, when compared to Existing Conditions and the No Project/No Action Alternative.

Implementation of Alternative A would result in alterations to natural river processes and characteristics, such as bank erosion, sinuosity, gradient, flow velocity, sediment transport, bed coarseness, depth, and width by changing the timing, distribution, and amount of flow in the Sacramento River between Shasta Dam and the Pacific Ocean. There would be operational impacts to the Sacramento River downstream of Keswick Dam, and extending into overflow areas, such as the Yolo Bypass, and the Sacramento-San Joaquin Delta, Suisun Bay, San Pablo Bay, and the San Francisco Bay to the Pacific Ocean, as a result of these hydraulic changes. The three Project intakes would also affect the amount of sediment and water in the river downstream of each diversion.

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[2] Other river systems within the Secondary and Extended study areas would experience impacts, but the impacts to the other river systems are considered to be less than significant because impacts to the Sacramento River are considered less than significant.

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Modeling results indicate that the effects of Alternative A on the Sacramento River would include a slight decrease in suspended sediment load and bed load (because of reduced flow and bed mobility) in the Sacramento River downstream of the Red Bluff Pumping Plant, GCID Canal, and the Delevan Pipeline intakes, mostly during winter months. The expected amount of sediment that would be entrained in these proposed intakes would be less than one percent of the existing changes in sediment deposition into the Delta.

The estimated average amount of suspended sediment currently moving in the river past the Bend Bridge gage is approximately 2.01 million tons (USACE, 1983). The average amount of suspended sediment that would be entrained at the Red Bluff Pumping Plant annually if Alternative A is implemented is estimated to be approximately 46,000 tons per year, as compared to 4,000 tons estimated for Existing Conditions and the No Project/No Action Alternative (Appendix 8A). Therefore, implementation of Alternative A would decrease the amount of suspended sediment in the Sacramento River downstream of the Red Bluff Pumping Plant by approximately 2.3 percent, as compared to the 0.2 percent decrease associated with Existing Conditions and the No Project/No Action Alternative at this location.

The amount of sediment that would be entrained at the GCID Canal Intake if Alternative A is implemented is estimated to be approximately 53,000 tons per year (Appendix 8A), as compared to 44,000 tons estimated for Existing Conditions and 47,000 tons estimated for the No Project/No Action Alternative. Therefore, implementation of Alternative A would decrease the amount of sediment in the Sacramento River downstream of Hamilton City by approximately 1.4 percent, as compared to the 1.1 percent decrease associated with Existing Conditions and the 1.2 percent decrease associated with the No Project/No Action Alternative at this location. At Hamilton City, there is a large component of flow and sediment that goes overbank during large flood events, so the actual percentage would be less.

The estimated annual amount of suspended sediment moving in the Sacramento River past the Butte City gage, which is approximately 10 miles upstream of the proposed Delevan Pipeline Intake location, is estimated at 4.32 million tons (USACE, 1983).Modeling results indicate that the amount of suspended sediment that would be entrained at the Delevan Pipeline Intake would be approximately 47,000 tons (Appendix 8A), representing approximately 1.1 percent of the amount of suspended sediment in the Sacramento River at that location. This intake is considered part of the Primary Study Area, but the downstream effects would occur in the Secondary Study Area.

The diverted suspended sediment at the three intake locations would be less than two percent of the total suspended sediment moving in this reach of the river. However, because the water and sediment would both be diverted, the concentration of the sediment in the water would remain unchanged, so there would be a **less-than-significant impact** on sediment concentration, turbidity or water clarity, when compared to Existing Conditions and the No Project/No Action Alternative.

The loss of suspended sediment would affect the river, floodplain, overflow areas, weirs, bypasses, the Delta, Suisun Bay, San Pablo Bay, San Francisco Bay, and the Pacific Ocean by reducing the amount of deposition in these areas. The impacts of the loss of suspended sediment at the existing Red Bluff Pumping Plant would occur in the Sacramento River from Red Bluff and downstream. The loss of suspended sediment at the existing GCID Canal Intake would occur in the Sacramento River from Hamilton City and downstream, and the loss of suspended sediment at the proposed Delevan Pipeline Intake would occur in the Sacramento River from the vicinity of Princeton and downstream. The effects would be considered **beneficia**l in some places, when compared to Existing Conditions and the No

Project/No Action Alternative, by reducing suspended sediment that could deposit in spawning gravel, agricultural fields, navigable waters, and in weirs and bypasses.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

Compared to Existing Conditions and/or the No Project/No Action Alternative, implementation of Alternative A is expected to affect natural Sacramento River meandering, bank erosion, and deposition, with consequent effects on riparian vegetation.

The installation of the fish screen at the proposed Delevan Pipeline Intake would be functionally equivalent to bank protection, and may affect meandering downstream of the diversion. However, the bank at this location consists of geologic control (erosion resistant unit). In addition, the existing Maxwell ID Pumping Plant, located immediately upstream of the proposed Delevan Pipeline Intake location, is located in a narrow section of the river and consequently acts as a local flow control point (Reclamation, 2012). Therefore, a **less-than-significant impact** is expected, when compared to Existing Conditions and the No Project/No Action Alternative.

Bank protection installed in the mid-1980s exists on the right bank in the bend upstream of the diversion, stabilizing the bend. This riprap does not protect the entire bend, and the potential for a partial cutoff exists.

The changes in streamflow downstream of Keswick Dam and the three Project intakes would also have effects on bank erosion. Decreased flows would potentially reduce the amount of sediment delivered to the Sacramento River from this source, at least directly downstream of the intakes. The largest effect would be associated with the existing Red Bluff Pumping Plant because of the 100 miles of meandering river occurring between the intake to the end of the meandering reach at the town of Colusa. The GCID Canal Intake would affect approximately 50 miles of meandering river, and the Delevan Pipeline Intake would have the least operational effect, affecting only approximately 10 miles of the Sacramento River, located downstream of the proposed intake.

The Reclamation meander study produced flow duration curves that indicate only minor differences in flow would occur between Existing Conditions, the No Project/No Action Alternative, and Alternative A. Most of the flow differences would occur below the threshold flow of 30,000 cfs, which is the flow above which significant geomorphologic river changes typically begin to occur.

The differences in channel migration between the Existing Conditions, the No Project/No Action Alternative, and Alternative A would be small. There would be a slight increase in bank erosion and meander rates with Alternative A (Appendix 8A). This is considered a **beneficial effect**, when compared to Existing Conditions and the No Project/No Action Alternative, because it would result in more benefits to riparian vegetation, fish, and wildlife because of a slight increase in floodplain rejuvenation.

Meandering is beneficial because it maintains forest health, complexity, and diversity by removing late stage older riparian vegetation, such as cottonwood forests on one side of the river, and replacing them with younger stages such as willow shrub on the other side. Trees, rootwads, and gravel (used by salmonids for habitat and spawning) would be introduced into the river and would also provide habitat for a variety of other fish and wildlife.

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Modeling performed using SRH-1DV and SacEFT indicates that the coverage of the riparian vegetation along the Sacramento River would increase or remain similar with implementation of Alternative A, when compared to Existing Conditions and the No Project/No Action Alternative.

It would typically be expected for the meander rates to decrease locally downstream of the Sacramento River winter diversions as a result of implementing Alternative A because the water diverted would reduce streamflow. However, this does not appear to be the case. The hydraulic modeling showed that the coordinated operation of the proposed Sites Reservoir and Shasta Lake would generally result in higher Shasta Lake storage in the late summer and early fall, and higher Keswick Dam releases in the fall and winter. Therefore, there would be a slight increase in the incidence of high flow events upstream of the intakes. The expected increase in flows upstream of the intakes, combined with the expected decrease in flows downstream of the intakes (due to diversion of excess flows primarily from tributaries), generally do not coincide. Therefore, it is expected that flow levels that are effective at increasing meander rates would increase slightly.

Alternative A would slightly increase erosion and slightly reduce sediment deposition. The change in the erosion-deposition balance with implementation of Alternative A would be small and is considered to be **less than significant** when considering the large natural fluctuations in these two parameters, and when compared to Existing Conditions and the No Project/No Action Alternative.

Downstream of Colusa, meandering would not occur to any significant degree because the river is confined by levees. Reduction of suspended sediment resulting from Alternative A downstream of Colusa is considered to be **less than significant**, when compared to Existing Conditions and the No Project/No Action Alternative, because the river is isolated by levees from its floodplain, and sediment deposition in the overflow areas is not considered environmentally beneficial. The weirs, bypasses, and overflow areas would benefit from the reduced deposition associated with operation of Alternative A because periodic removal of sediment is required to maintain their proper function.

Reduced suspended sediment supply has the potential to affect the replenishment of sand on ocean beaches south of San Francisco. However, the Sacramento and San Joaquin rivers are not significant suppliers of sand to the beaches, partly because of the many dams on those rivers, and also because of the low gradient through the Sacramento-San Joaquin Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay to the Pacific Ocean. All but the very fine sediment drops out before reaching the ocean. Other streams that feed directly into the ocean, such as the Klamath, Mad, Van Duzen, Eel, Russian, and other smaller rivers, provide the majority of the sand to beaches. **No impact** would occur to sand deposition on beaches depending on these rivers, when compared to Existing Conditions and the No Project/No Action Alternative.

Impact Geom-3: Substantial Alteration of the Amount of Large Woody Debris, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

Compared to Existing Conditions and/or the No Project/No Action Alternative, Alternative A would result in impacts on fish and wildlife habitat by affecting the amount of large woody debris, shaded riverine aquatic habitat, and spawning gravel in the river. The slight increase in bank erosion would increase the number of trees in the river used by fish as cover and holding habitat, and the amount of gravel used for spawning. The gravel would become part of the sediment supply in the river, and would move as bedload. The bedload would deposit on riffles where salmon build their nests and deposit their eggs.

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Modeling performed using SacEFT indicates that the large woody debris recruitment to the Sacramento River would remain similar with implementation of Alternative A, when compared to Existing Conditions and the No Project/No Action Alternative.

It is not certain how Alternative A would affect the shaded riverine aquatic habitat that occurs along the banks of a stream; however, it is expected that the increased bank erosion would result in improved riparian forest health.

No bedload is expected to be entrained in the three Project intakes, but the reduced flow downstream of those intakes would reduce the mobility of the bedload in the channel. This may have a slight aggradational effect to the channel downstream of each intake because bedload derived from bank erosion and tributaries would continue to move into the area. This would be a **beneficial effect** to salmon spawning gravel riffle habitat, when compared to Existing Conditions and the No Project/No Action Alternative.

Bedload is the main source of spawning gravel for salmonids. The salmon depend on fresh gravel, free from fine sediment, to deposit their eggs. Bedload movement on a periodic basis is important in maintaining high spawning gravel quality. Bedload deposition is also important in maintaining hydraulic diversity. Islands, point bars, and multiple channels provide a variety of habitat elements for the fish and wildlife.

Reclamation modeling of the movement of bedload sediment for Alternative A indicates that the bedload transport capacity upstream of the Red Bluff Pumping Plant intake would increase by two to six percent, and would decrease by approximately two percent downstream (Appendix 8A). Alternative A would affect the movement of gravel and the overall bedload budget by less than five percent, which is considered to not significantly affect the bedload sediment balance in the Sacramento River. Some aggradation and degradation would occur in the different reaches; the amounts are small, less than 0.1 inch per year (Appendix 8A).

The GCID Canal Intake has an existing bedload deposition problem at the mouth of the river intake channel. Dredging to remove these deposits currently occurs infrequently, every five years or so. Implementation of Alternative A may slightly increase the frequency and amount of dredging that would need to occur. Similar maintenance activities may be required at the Red Bluff Pumping Plant and the Delevan Pipeline Intake. If the gravel is removed from the river permanently, it is a negative impact. However, the gravel may be spread on point bars downstream of the intakes, essentially re-introducing the gravel and minimizing the effects of this activity. Modeling results (Appendix 8A) indicate that the change in hydrology that would be associated with the operation of Alternative A would result in a **less-than-significant impact** on bedload movement, when compared to Existing Conditions and the No Project/No Action Alternative.

The slight increase in bank erosion rates mentioned previously (Appendix 8A) is expected to have a slightly **beneficial effect** on riparian vegetation over the long-term, when compared to Existing Conditions and the No Project/No Action Alternative. Increased erosion would result in more of the floodplain being converted back to riparian vegetation. Shaded riverine aquatic habitat would also increase because more of the floodplain would be occupied by riparian forests, and more woody material and spawning gravel would be introduced to the river.

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8.3.6.3 Primary Study Area – Alternative A

Construction, Operation, and Maintenance Impacts

Delevan Pipeline Intake Facilities

Impact Geom-1: Substantial Alteration of Natural River Processes and Characteristics

The only location along the Sacramento River where Alternative A construction, operation, and maintenance activities would occur, and where impacts from/to Sacramento River fluvial geomorphology would occur, is at the proposed Delevan Pipeline Intake Facilities location.

The proposed pump station and afterbay would be located on erosion resistant deposits (referred to as geologic control) of the Modesto Formation. The proposed fish screen, floodgates, and pipes leading to the afterbay, would be located on river deposits in the 1896 to 1937 channel alignment (Figure 8-3).

When compared to Existing Conditions and/or the No Project/No Action Alternative, the proposed fish screens, as part of Alternative A, would stabilize a short section of bank, and are expected to be the only feature that could affect Sacramento River geomorphology directly. However, the bank where the fish screens would be constructed is considered to be geologic control and not part of the meander belt. The construction of the screens would result in a **less-than-significant impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

Refer to the **Impact Geom-1** discussion for the Sacramento River within the Secondary Study Area for a discussion of the operation and maintenance impacts associated with the two existing intakes (Red Bluff Pumping Plant and GCID Canal) and the proposed Delevan Pipeline intake. There may be some minor changes in sediment levels and local flow around the proposed Delevan Pipeline Intake construction area, when compared to Existing Conditions and/or the No Project/No Action Alternative. These changes in sediment and flow would not affect the local geomorphology in the Sacramento River and would, therefore, have **no impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

The proposed fish screens would result in the local removal of riparian vegetation along this short length of bank, reducing habitat complexity, when compared to Existing Conditions and/or the No Project/No Action Alternative. The impact would be slight and is considered to be **less than significant**.

Impact Geom-3: Substantial Alteration of the Amount of Large Woody Debris, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

The bank where the proposed Delevan Pipeline Intake fish screens would be located consists of geologically stable units that do not erode significantly. The reduction in spawning gravel and fish habitat would be slight, when compared to Existing Conditions and/or the No Project/No Action Alternative, and is considered to be a **less-than-significant impact**.

8.3.7 Impacts Associated with Alternative B

8.3.7.1 Extended Study Area – Alternative B

Construction, Operation, and Maintenance Impacts

The impacts associated with Alternative B, as they relate to natural river processes and characteristics (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**), would be the same as described for Alternative A for the Extended Study Area.

8.3.7.2 Secondary Study Area – Alternative B

Construction, Operation, and Maintenance Impacts

The impacts associated with Alternative B operations, as they relate to natural river processes and characteristics (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**), would be the same as described for Alternative A for Trinity Lake, Lewiston Lake, Trinity River, Klamath River Downstream of the Trinity River, Whiskeytown Lake, Spring Creek, Shasta Lake, Keswick Reservoir, Clear Creek, Lake Oroville, Thermalito Complex, Feather River, Sutter Bypass, Yolo Bypass, Folsom Lake, Lake Natoma, American River, Sacramento-San Joaquin Delta, Suisun Bay, San Pablo Bay, San Francisco Bay, and for the Sacramento River as it pertains to the construction impacts associated with the pump installation at the Red Bluff Pumping Plant.

Operational impacts associated with implementation of Alternative B to the Sacramento River downstream of Shasta Dam to the Pacific Ocean are discussed below.

Sacramento River

Impact Geom-1: Substantial Alteration of Natural River Processes and Characteristics

Suspended sediment entrained into the existing Red Bluff Pumping Plant would be somewhat higher for Alternative B than that described for Alternative A (approximately 58,000 tons per year instead of 46,000 tons) (Appendix 8A) because of the larger diversion amounts that would be needed to fill the larger 1.8 MAF Sites Reservoir, and because the Delevan Pipeline Intake would be replaced by the release-only Delevan Pipeline Discharge Facility.

The amount of suspended sediment entrained at the existing GCID Canal Intake, as a result of Alternative B, also would be a little higher than for Alternative A (64,000 instead of 53,000 tons per year), but no sediment would be entrained at the proposed Delevan Pipeline Discharge Facility because there would be no intake there. These impacts would extend downstream in the Secondary Study Area, primarily in the Sacramento River downstream of Hamilton City through the Delta and to the Pacific Ocean. Although Alternative B impacts would be slightly larger to the meandering reach of the river than Alternative A because the water is removed farther upstream in the system, Alternative B operation would still result in a **less-than-significant impact** on the amount of suspended sediment when compared to the large amount of sediment moving in the river (as described in the Alternative A analysis), when compared to Existing Conditions and the No Project/No Action Alternative.

The movement of bedload downstream of the two existing intakes would decrease slightly, when comparing Alternative B to Alternative A because of the reduced flow in the channel. The impact of the reduced bedload movement is considered to be **less than significant** for Alternative B, when compared to Existing Conditions and the No Project/No Action Alternative.

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Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

Because of the slight differences in the hydrology between Alternative A and Alternative B, the differences in meandering, bank erosion and deposition are also slight. Alternative B would result in less natural river meandering than Alternative A, which would result in less bank erosion and deposition, with less consequent alteration of riparian vegetation regeneration and habitat complexity. The meandering is only slightly more for Alternative B than for Existing Conditions and the No Project/No Action Alternative. As discussed for Alternative A, these differences are considered to be small, when compared to the natural variation in these parameters. Therefore, the consequent alteration of riparian vegetation regeneration and habitat complexity is considered to be **beneficial, but less than significant**, when compared to Existing Conditions and the No Project/No Action Alternative.

Modeling performed using SRH-1DV and SacEFT indicates that the coverage of the riparian vegetation along Sacramento River would increase or remain similar with implementation of Alternative B, when compared to Existing Conditions and the No Project/No Action Alternative. The only exception is that the SacEFT indicates that there would be a slightly higher number of years with post-initiation scour risk for Fremont Cottonwood seedlings with implementation of Alternative B, when compared to the No Project/No Action Alternative.

Impact Geom-3: Substantial Alteration of the Amount of Large Woody Debris, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

Alternative B would affect large woody debris, shaded riverine aquatic habitat, and spawning gravel in the Sacramento River, which could result in a loss of fish rearing, holding, spawning, and feeding habitat. However, modeling performed using SacEFT indicates that the large woody debris recruitment to the Sacramento River would remain similar with implementation of Alternative B, when compared to Existing Conditions and the No Project/No Action Alternative. As discussed for Alternative A, implementation of either of these action alternatives would result in a slight increase in bank erosion and meandering (Appendix 8A), when compared to Existing Conditions and the No Project/No Action Alternative, resulting in a **less-than-significant, but beneficial, impact** due to the increase in large woody debris, shaded riverine aquatic habitat, and spawning gravel in the river.

8.3.7.3 Primary Study Area – Alternative B

Construction, Operation, and Maintenance Impacts

Delevan Pipeline Discharge Facility

Impact Geom-1: Substantial Alteration of Natural River Processes and Characteristics

As described for the Delevan Pipeline Intake Facilities, the Delevan Pipeline Discharge Facility would also be located on geologic control outside of the Sacramento River meander belt. The discharge facility would have no associated fish screens, and therefore, would not extend into the river, but would require a cofferdam that would extend into the river during Project construction. However, the construction area would also be located on geologic control. The discharge facility would be operated as a release-only facility, and would, therefore, not entrain sediment during operation or require the maintenance activity of sediment removal that was described for the intake facility associated with Alternative A. Construction, operation, and maintenance of the Delevan Pipeline Discharge Facility would, therefore, result in a

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less-than-significant impact to Sacramento River geomorphology in the Primary Study Area, when compared to Existing Conditions and/or the No Project/No Action Alternative.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

The proposed discharge facility would result in less riparian vegetation being removed along this length of bank when compared to Alternative A. Because of the short length of bank affected, the impact would be slight and is considered to be **less than significant**, when compared to Existing Conditions and the No Project/No Action Alternative.

Impact Geom-3: Substantial Alteration of the Amount of Large Woody Debris, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

The bank where the proposed Delevan Pipeline Discharge Facility would be located consists of geologically stable units that do not erode significantly. The reduction in fish habitat resulting from the loss of a small amount of shaded riverine aquatic habitat would be slight, when compared to Existing Conditions and/or the No Project/No Action Alternative, and is considered to be a **less-than-significant impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

8.3.8 Impacts Associated with Alternative C

8.3.8.1 Extended Study Area – Alternative C

Construction, Operation, and Maintenance Impacts

The impacts associated with Alternative C, as they relate to natural river processes and characteristics (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**), would be the same as described for Alternative A for the Extended Study Area.

8.3.8.2 Secondary Study Area – Alternative C

Construction, Operation, and Maintenance Impacts

The impacts associated with Alternative C operations, as they relate to natural river processes and characteristics (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**), would be the same as described for Alternative A for Trinity Lake, Lewiston Lake, Trinity River, Klamath River Downstream of the Trinity River, Whiskeytown Lake, Spring Creek, Shasta Lake, Keswick Reservoir, Clear Creek, Lake Oroville, Thermalito Complex, Feather River, Sutter Bypass, Yolo Bypass, Folsom Lake, Lake Natoma, American River, Sacramento-San Joaquin Delta, Suisun Bay, San Pablo Bay, San Francisco Bay, and for the Sacramento River as it pertains to the construction, operation, and maintenance impacts associated with the pump installation at the Red Bluff Pumping Plant.

Operational impacts associated with implementation of Alternative B for the Sacramento River downstream of Shasta Dam to the Pacific Ocean are discussed below.

Sacramento River

Impact Geom-1: Substantial Alteration of Natural River Processes and Characteristics

The implementation of Alternative C would alter hydraulic conditions in the Sacramento River and result in changes to natural river processes and characteristics such as bank erosion, sinuosity, gradient, flow velocity, sediment transport, bed coarseness, depth, and width.

The impacts to hydrology from operation of Alternative C would be slightly larger than for Alternative A because the larger reservoir associated with Alternative C would allow more diversions to occur, which could increase the amount of diverted sediment. However, as discussed for Alternative A, the diverted suspended sediment at the three Project intake locations would represent a small percentage of the total suspended sediment in this reach of the river, and because the water and sediment would both be diverted, the concentration of the sediment in the water would remain unchanged. There would, therefore, be a **less-than-significant impact** to the Sacramento River natural river processes, such as bank erosion, sinuosity, gradient, flow velocity, sediment transport, bed coarseness, depth, and width, when compared to Existing Conditions and the No Project/No Action Alternative.

The movement of bedload downstream of the two existing intakes would be similar, when comparing Alternative C to Alternative A, because of similar flow in the channel, and is considered to be **less than significant** for Alternative C, when compared to Existing Conditions and the No Project/No Action Alternative.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

Alternative C would result in a slight increase in natural meandering, bank erosion, and deposition, with a consequent slight increase in riparian vegetation regeneration and habitat complexity, when compared to the No Project/No Action Alternative. The accumulated channel migration distance (Appendix 8A) showed the results of the meander modeling for Alternative A. Alternative C would result in less channel migration distance than Alternative A, but more than Alternative B. All three action alternatives would differ by less than 10 feet of channel migration for the 30-year model period. The average meander distance would be approximately 175 feet for all three alternatives, with an associated potential increase of approximately a maximum of six percent. This is considered a beneficial effect to the environment, when compared to Existing Conditions and the No Project/No Action Alternative.

Impact Geom-3: Substantial Alteration of the Amount of Large Woody Debris, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

Modeling performed using SacEFT indicates that the large woody debris recruitment to the Sacramento River with implementation of Alternative C would be the same as described for Alternative A. As discussed for Alternative A, implementation of either of these action alternatives would result in a slight increase in bank erosion and meandering (Appendix 8A), when compared to Existing Conditions and the No Project/No Action Alternative, resulting in a **less-than-significant, but beneficial, impact** due to the increase in large woody debris, shaded riverine aquatic habitat, and spawning gravel in the river.

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8.3.8.3 Primary Study Area – Alternative C

Construction, Operation, and Maintenance Impacts

Similar to Alternative A, Alternative C would include the Delevan Pipeline Intake Facilities within the Primary Study Area. The impacts associated with Alternative C, as they relate to natural river processes and characteristics (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**), would, therefore, be the same as described for Alternative A for the Primary Study Area.

8.4 Mitigation Measures

Because no significant or potentially significant impacts were identified, no mitigation is required or recommended.

8.5 References

California Department of Water Resources (DWR). 2010. *Sacramento River Bank Erosion Investigation - Red Bluff to Colusa, California*. Northern Region Office District Draft Report. 206p. June. Page cited: 181.

U.S. Bureau of Reclamation (Reclamation). 2012. North of Delta Off-stream Storage Investigation Feasibility Report. Administrative Draft. Volume 2, Appendix B: Engineering. June 2012.

U.S. Army Corps of Engineers (USACE). 1983. *Sediment Transport Studies*. Sacramento River and Tributaries Bank Protection and Erosion Control Investigation, California. Sacramento District. 60 p. plus figures. August. Pages cited: Figure 10 in Appendix.

U.S. Geological Survey (USGS). 1977. *Lateral Migration of the Middle Sacramento River, California*. Water Resources Investigation 77-43. 51 p. Pages cited: 43 and 50.

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Figures

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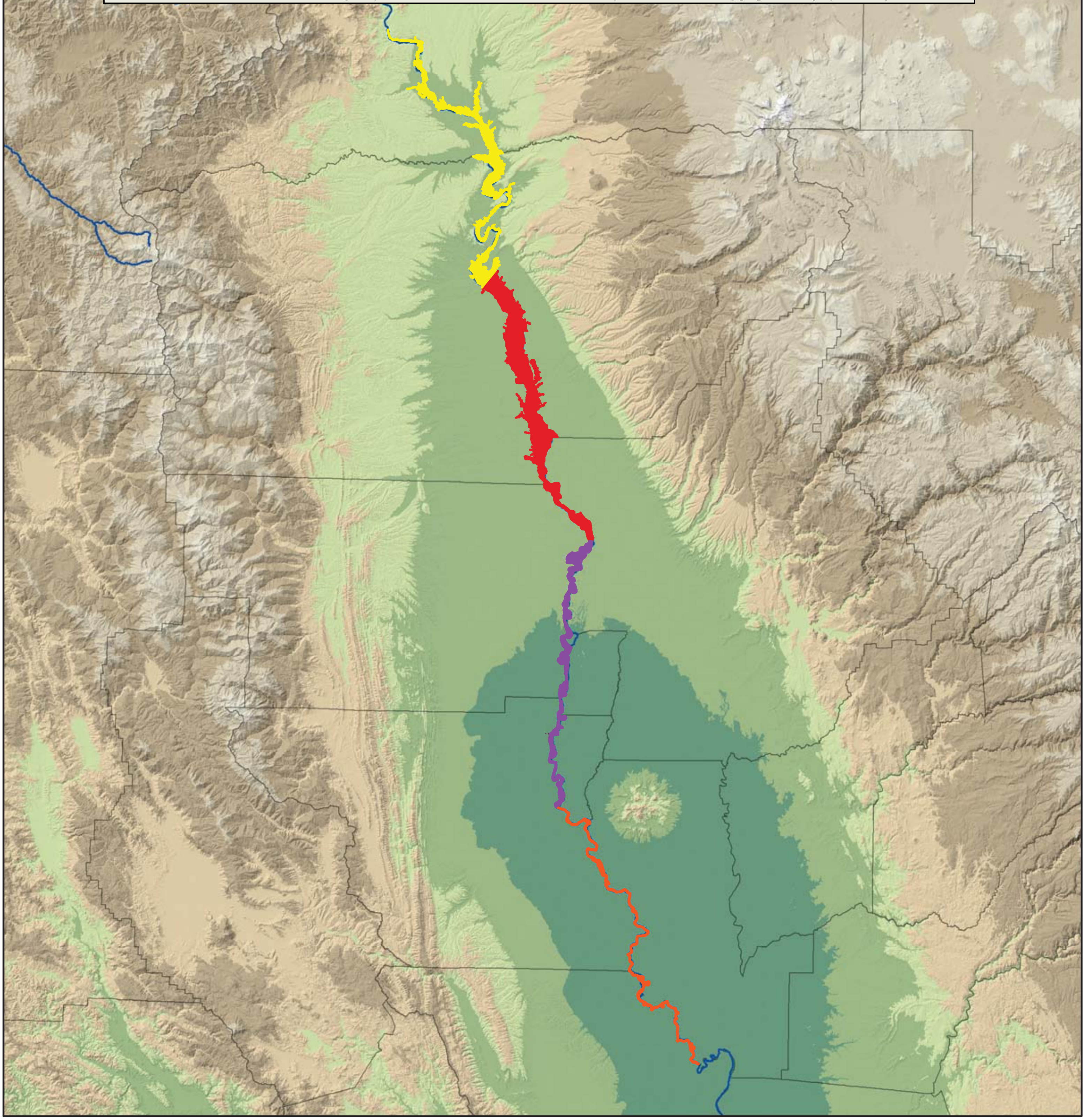

Legend

Sacramento River Reaches

- Keswick Dam to Red Bluff Diversion Dam
- Red Bluff Diversion Dam to Chico Landing (RM 193)
- Chico Landing (RM 193) to Colusa Bridge
- Colusa Bridge to Verona (Confluence with the Feather River)
- Rivers

FIGURE 8-1
Sacramento River Reaches
North-of-the-Delta Offstream Storage Project

N

0 5 10 20 30 Miles

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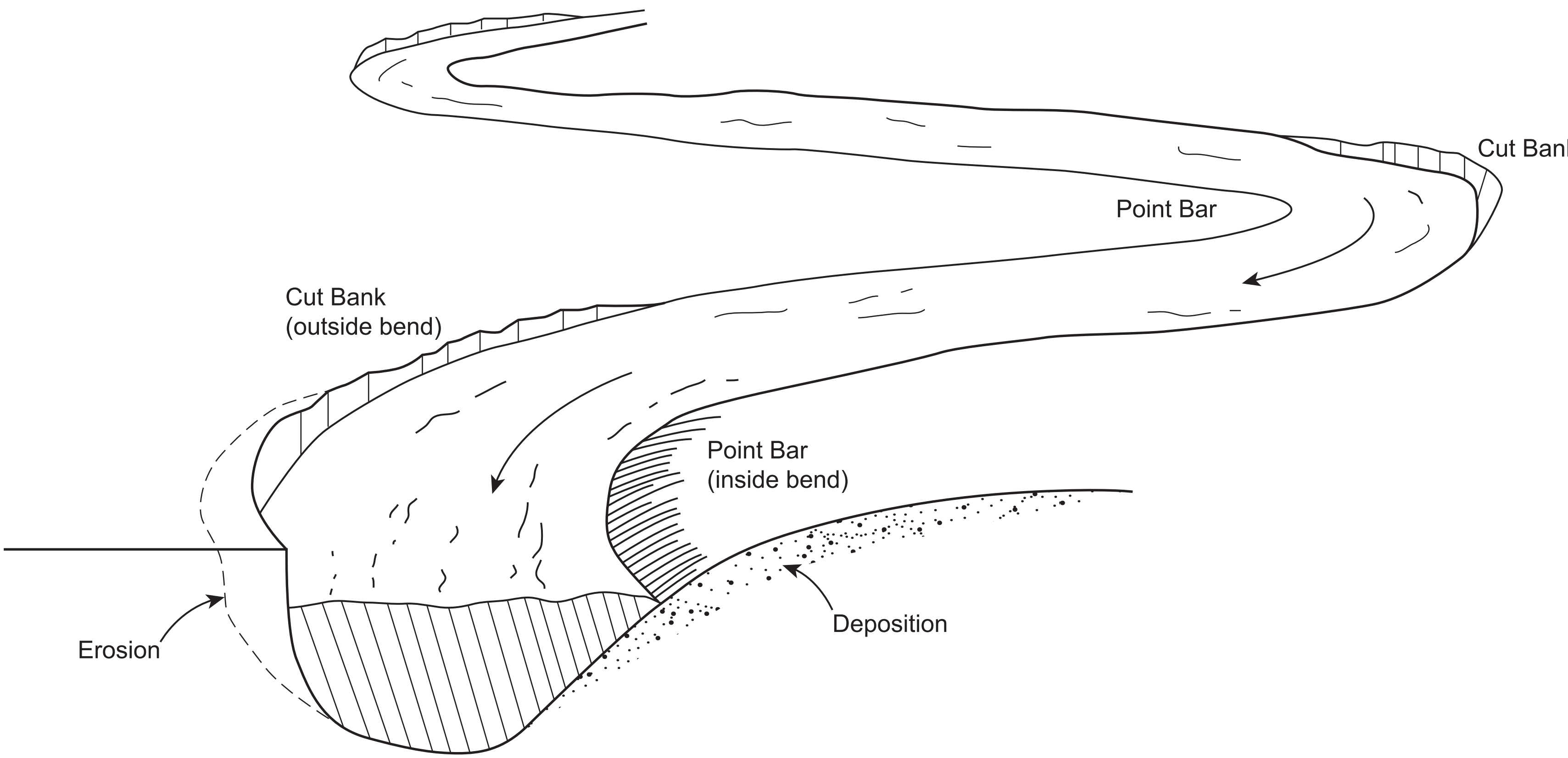

FIGURE 8-2
Typical Bend on a Meandering River
North-of-the Delta Offstream Storage Project

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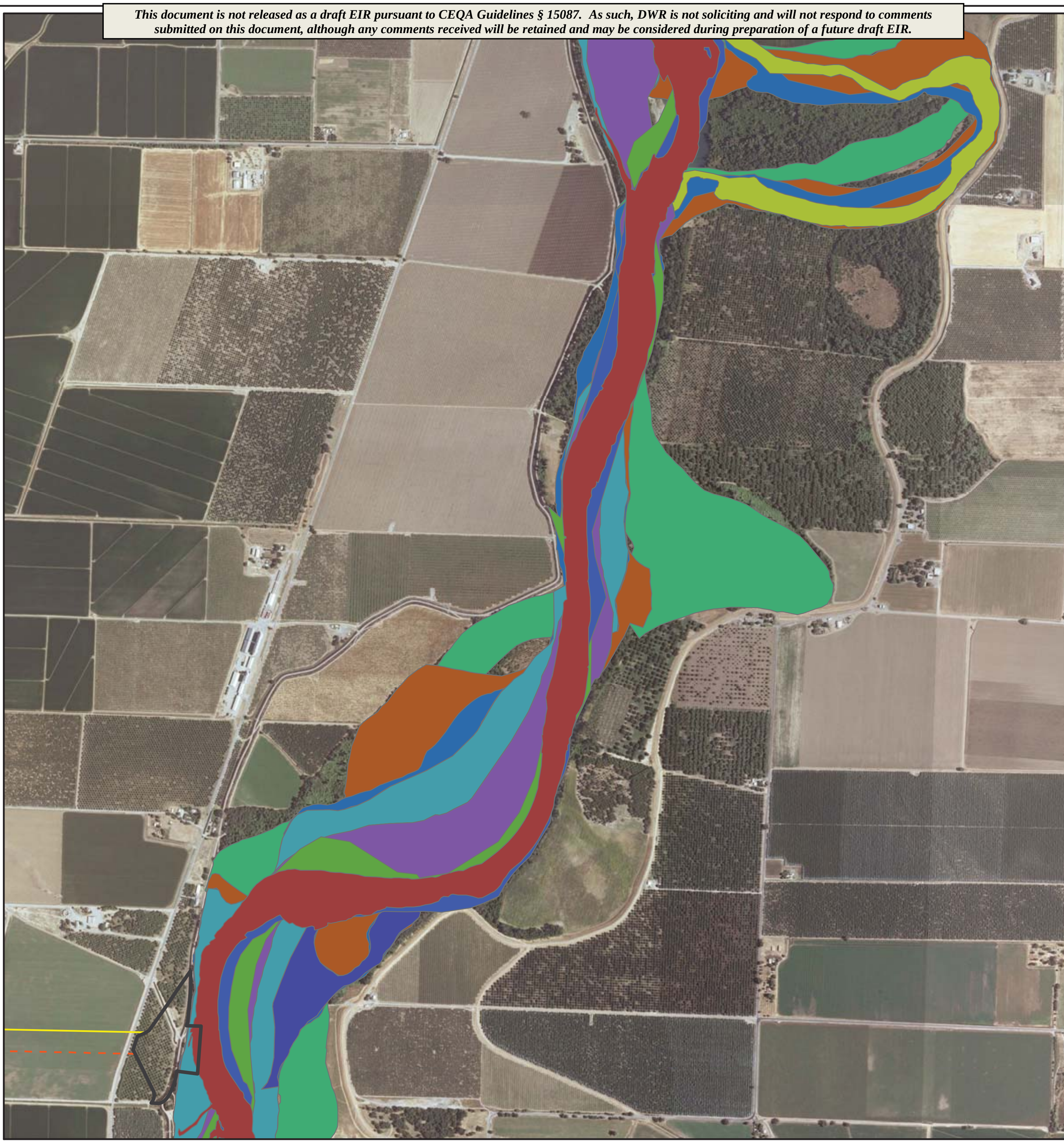

Legend

Historic River Channels by Year

- 1896
- 1908
- 1923
- 1935
- 1937
- 1946
- 1955
- 1956
- 1960
- 1964
- 1969
- 1976
- 1981
- 1991
- 1997

- Delevan Pipeline Intake Structure
- Delevan Transmission Line
- Delevan Pipeline

FIGURE 8-3
Sacramento River Channel Changes At and Near River Mile 158.5
North-of-the-Delta Offstream Storage Project

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Legend

Delevan Pipeline Intake Structure

Delevan Transmission Line

Delevan Pipeline

FIGURE 8-4
Gravel Bars and Mid-Channel Islands Near River Mile 158.5

North-of-the-Delta Offstream Storage Project

N

0 250 500 1,000 1,500 2,000 Feet